TACIT COLLUSION IN THE AWS-1 AUCTION: THE SIGNALING PROBLEM[1]

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[1] The author is particularly grateful to Dr. Jesses A. Schwartz who graciously shared algorithms developed for his analysis of the PCS D, E, and F auctions.

ABSTRACT

This study utilizes the methodology developed by Peter Cramton and Jesse A. Schwartz in their 2002 paper on tacit collusion in the PCS D, E, and Block auction to identify signaling behaviors by bidders in the AWS-1 auction and measure their effects. The principal signaling behavior identified was retaliatory bidding, which occurred in the AWS-1 auction at a slightly higher level than in the PCS D, E, and F auction. Significant indirect demand reduction effects were observed in the AWS-1 auction which call into question whether the auction was revenue maximizing. The study concludes that signaling remains a serious problem for FCC spectrum auctions and recommends that anonymous bidding rules be adopted for the 700 MHz and all future FCC spectrum auctions.

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Prolegoumenon: A Tale of Anonymous Bidding.

Economic theories about competition and efficiency, and a conviction that auctioning spectrum would maximize revenue, were the basis on which Congress and the FCC authorized spectrum auctions With the accumulation of empirical evidence from actual spectrum auctions, the distance between theory and practice became increasingly apparent: bidders ued the auction rules to engage in behaviors which hampered competition and reduced the efficiency of the resulting allocations, and which threatened the expect revenue maximization which auction theorists had promised. As early as 1999 Peter Cramton and Jesse Schwartz circulated a paper which identified tacitly collusive, anti-competitive behaviors on the part of bidders – code bidding and retaliatory bidding – in the PCS D, E, and F Block auction of 1996-97.[2] These signaling behaviors were used by bidders to gain a reputation for imposing costs on those who dared to bid against them and were used to limit the ability of new entrants, fearful of retaliation, to effectively compete against some established incumbents. Most importantly, such signaling behaviors led to significant demand reduction and concomitant loss of revenue. Such signaling behaviors were possible only under conditions of open bidding.[3]

On another front, the "Linkage Principle,"[4] as it has been termed by Paul Milgrom, came under increasing attack from 1999 to 2004. The "Linkage Principle"

[2] Peter Cramton and Jesse A. Schwartz, "Collusive Bidding in FCC Spectrum Auctions," working paper, University of Maryland, 1999; the paper was later published as "Collusive Bidding in FCC Spectrum Auctions," *Contributions to Economic Policy & Analysis*, I:1 (2002), article 11.

[3] A 1999 German spectrum auction provided further evidence of collusive allocations in open-bid, ascending auctions: Mannesmann and T-Mobil essentially negotiated a division of the blocks. *Viz*., P. Jehiel and B. Moldovanu, "A Critique of the Planned Rules for the German UMTS/IMT-2000 License Auction," working paper, University College London and University of Mannheim, 2000, and V. Grimm, F. Riedel, and E. Wolfstetter, "The Third Generation (UMTS) Spectrum Auction in Germany." *ifo Studien*, 48 (2002), 123–143.

[4] Paul Milgrom and Robert Weber, "The Theory of Auctions and Competitive Bidding", *Econometrica*, 50 (1982).

holds that auction structures which disclose more information to bidders increase auction revenue. This "principle" has been shown to be false for auctions in which multiple objects and multidimemnsional bidder types are present.[5] This was particularly important because the "Linkage Principle" is the principal theoretical rationale for open bidding. Both empirical and theoretical evidence emerged that open auctions – auctions in which the identities and bids of all bidders were disclosed to the rest of the bidders – could produce anti-competitive, inefficient, and revenue non-maximizing outcomes.

Leslie Marx, the FCC's Chief Economist, resolved to do something in response to the growing mass of evidence that open auctions were problematic, and in connection with the upcoming AWS-1 auction proposed rules for anonymous bidding. The FCC's anonymous bidding proposal was enthusiastically supported by the U.S. Department of Justice, the Federal Trade Commission, and numerous consumers organizations and public interest groups. The incumbents who were planning to bid in the AWS-1 auction launched a firestorm of criticism and an intense political campaign to prevent the adoption of anonymous bidding, including a letter to Chairman Martin threatening not to participate in the auction.[6] As one lobbyist for the incumbents told *Communications Daily*, "You can't go to the FCC and argue with an economist. This is a political play. These are businesses and this is of critical importance to these businesses. Economic

[5] Motty Perry and Philip J. Reny, "On the Failure of the Linkage Principle in Multi-Unit Auctions," *Econometrica*, 67 (1999). More recent scholarship has extended finding of failure of the "Linkage Principle" to a wider range of auction structures: Vijay Krishna, *Auction Theory* (San Diego, CA, 2002); Thierry Foucault and Stefano Lovo, "Linkage principle, Multi-dimensional Signals and Blind Auctions." working paper, HEC School of Management, 2003; S. Board, "Revealing Information in Auctions: The Efficiency Effect," working paper, University of Toronto, 2004.

[6] Interestingly, Verizon did not oppose anonymous bidding.

theories be damned ... We'll be suited up and at the FCC." [7] Seldom have the incumbents been so frank.

The principal arguments assembled by the incumbents were that there was no need for the rules change and that anonymous bidding would prevent bidders from assessing appropriate complementarities as they bid to aggregate packages of spectrum in accordance with their business plans. Some smaller bidders weighed in with the argument that anonymous bidding prevented them from avoiding head-to-head bidding wars with the major incumbents. Consumers organizations and public interest groups argued that the problems of signaling and other anti-competitive behaviors were real and only anonymous bidding could resolve them-- especially the problem that the incumbents used open bidding to identify new entrants for exclusion from acquiring spectrum, that bidders who hadn't decided before the bidding began on complementarities among the licenses which they were seeking were admitting to having no bidding strategy, and that smaller bidders like rural telephone companies were seldom challenged by major incumbents for the spectrum on which they routinely bid. In the end, resolution of the matter of anonymous bidding was not a question of arguments, but of political muscle.

T-Mobile proposed a compromise: anonymous bidding would not be used in the AWS-1 auction unless the modified eligibility ratio fell below three, i.e., unless the eligibility of qualified bidders produced a mean of less than three bidders per license. The FCC adopted the compromise.

It is interesting that the AWS-1 auction had among its qualified bidders four which never placed a bid, and seven which bid only once. Given how narrowly the

[7] *Communications Daily*, March 28, 2006.

modified eligibility ratio reached 3.05, if these marginal bidders had not been present, the auction would have been anonymous. There was certainly the impression left that the auction rules were gamed by the introduction of "qualified" bidders whose presence was solely to ensure that a modified eligibility ratio of three was achieved so that the AWS-1 auction would not be anonymous. The vigor with which several incumbents opposed anonymous bidding raises the question of whether they had any hand in arranging the participation of these "ratio pumping" bidders in the auction. At the least, the AWS-1 auction experience suggested that "compromises" which introduce artificial conditions for implementation of anonymous bidding were an invitation for the rules to be gamed.

Anonymous bidding did not occur in the AWS-1 auction, and thus it provided a test of whose claims were the true: the incumbents or their opponents.

I. Signaling Behaviors Are a Threat to Revenue Maximization in FCC Auctions

A. Theoretical Evidence.

Signaling represents a direct threat to revenue maximization in FCC spectrum auctions. A considerable theoretical literature exists which points to the demand reduction effects of signaling and similar tacitly collusive strategies in simultaneous, open, ascending multi-object auctions.[8] The underlying intuition is that to the extent to

[8] M.S. Robinson, "Collusion and the Choice of Auction." *The RAND Journal of Economics*, 16 (1985), 141–145; George Mailath, George and Peter Zemsky, "Collusion in Second Price Auctions with Heterogeneous Bidders," *Games and Economic Behavior*, 3 (1991); F. Menezes, "Multiple-unit English Auctions," *European Journal of Political Economy*, 12 (1996), 671–684; R.J. Weber, "Making More from Less: Strategic Demand Reduction in the FCC Spectrum Auctions," *Journal of Economics and Management Strategy*, 6 (1997), 529–548; Richard Engelbrecht-Wiggans and Charles M. Kahn, "Low Revenue Equilibria in Simultaneous Auctions," working paper, University of Illinois, 1999; L. M. Ausubel and Peter Cramton, "Demand Reduction and Inefficiency in Multi-Unit Auctions," working paper, University of Maryland, 1999; Peter Cramton and Jesse Schwartz, "Collusive Bidding: Lessons from the FCC Spectrum Auctions," *Journal of Regulatory Economics*, 17 (2000); Robert C. Marshall and Michael J. Meurer, "The Economics of Bidder Collusion," in K. Chatterjee and W.F. Samuelson, eds., *Game Theory and Business Applications* (Norwell, MA., 2001); Sandro Brusco and Giuseppe Lopomo, Giuseppe, 2002. "Collusion via Signalling in Simultaneous Ascending Bid Auctions with Heterogeneous Objects, with and without Complementarities," *Review of Economic Studies*, 69:2 (2002).

which retaliation forces competitors out of bidding for a license the retaliating bidder obtains the license at a lower price than would otherwise obtain, reducing revenue from the auction by reducing demand from bidders threatened by retaliation. As Brusco and Lopomo note,

> The presence of multiple objects facilitates collusion by allowing the bidders to signal their willingness to abstain from competing over certain objects, provided they are not challenged on others. In this way, the bidders can allocate the objects among themselves without paying much.[9]

As noted above the problem of signaling is one more example of how the "Linkage Principle" is falsified.

B. The Cramton-Schwartz Empirical Studies of the PCS D, E, and F Block Auction.

In 1999 Peter Cramton and Jesse A. Schwartz circulated the results of an extensive study of code bidding and retaliatory bidding, two primary methods of signaling, in the Personal Communications Services (PCS) auction for broadband frequency blocks D, E, and F (auction 11), held from August 1996 to January 1997. [10] While Cramton and Schwartz found relatively small direct demand reduction effects in this auction -- $29.8 million to $38.1 million, depending on the estimation method – they found that signaling bidders paid 36 percent less than non-signaling bidders for the D and E blocks and 18 percent less for the F block. As they concluded, "[g]iven that signaling bidders won about 40% of the available licenses, this indicates that the indirect losses associated with signaling may be quite large."[11]

In 2000 Cramton and Schwartz published more evidence of collusion arising from

[9] *Op. cit.*, 1.

[10] Peter Cramton and Jesse A. Schwartz, "Collusive Bidding in FCC Spectrum Auctions," working paper, University of Maryland, 1999; the paper was later published as "Collusive Bidding in FCC Spectrum Auctions," *Contributions to Economic Policy & Analysis*, I:1 (2004), article 11.

[11] *Ibid.*, 28.

signaling in the PCS D, E, and F Block auction.[12] They found a pattern which confirmed the demand reduction effects of retaliatory bidding. AT&T was both the most successful bidder and a retaliatory bidder:

> One reason for avoiding a bidder is because the bidder has a reputation for blanket retaliation or other types of aggressive bidding. Another reason to avoid a bidder is that if the bidder has deep financial resources, then there is little reason to believe that a license can be won if that bidder is interested in it. Note that these reasons are not mutually exclusive. If a bidder thinks that the other bidder has a large enough budget to win any license it wants, and there is some probability that the bidder protects the licenses it wants with retaliation, then to bid against this bidder risks a substantial cost—namely, raising the prices on the other licenses the bidder wants. Suppose there is one large bidder that wants many licenses in the auction. If it is possible to keep the prices low on the licenses this bidder will win, then this bidder may be willing to demand reduce. It sacrifices some licenses it values in order to keep its overall prices low. Thus, bidders have the incentive to avoid the large bidder, letting the large bidder win the licenses it wants at low prices.
>
> Though our reasons why bidders avoid certain others are speculative, that this is a real phenomenon is not. In the DEF auction, AT&T won 223 licenses—more licenses than anyone else. These licenses covered 140 million people, over 50% more than any other bidder. To explore whether bidders avoided AT&T, we looked at all of the bids that occurred after round 10 on the D and E blocks in markets on which AT&T was the high bidder. We ask the question: Did bidders bump AT&T when AT&T was the high bidder on the less expensive of the two blocks? If bidders did not care about the identity of the high bidder, they would arbitrage the prices of the D and E blocks, and bid against AT&T if the other block was more expensive. This did not happen. When the other block was 15% more expensive (the bidding increments were 5% or 10% of the standing high bid in the DEF auction), bidders still bid on the other block 32% of the time rather than bid against AT&T on the less costly block. When the other block was 25% more expensive, bidders still avoided AT&T 31% of the time. Even when the price of the other block was 50% higher, bidders bid on the higher priced block 27% of the time.
>
> As a comparison, we performed this same exercise to see if bidders systematically avoided smaller bidders in the same way. We chose five bidders who won between 9 and 14 licenses—ACCPCS, Comcast, Rivgam, PAccess, and Touch. We counted all of the bids made by other bidders when one of these five bidders was the standing high bidder on the D or the E block. When the other blocks were 15%, 25%, and 50% more expensive, bidders avoided these five bidders 20%, 18%, and 15% of the time, respectively.[13]

Thus, AT&T was able to deter other bidders from challenging it at a statistically significant rate far greater than a representative sample of smaller bidders. The tacitly collusive allocation of licenses which resulted exhibited demand reduction.

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[12] Peter Cramton and Jesse A. Schwartz, "Collusive Bidding: Lessons from the FCC Spectrum Auctions," *Journal of Regulatory Economics*, 17 (2000), 229-252.

[13] *Op. cit.*, 245-46. Cramton and Schwartz also make the point that both retaliatory bidding and sheer size had the deterrent effective, a point worth remembering when considering the asymmetrical capitalization of incumbents in most auctions.

II. Methodology

This study is in large part a replication of the Cramton and Schwartz 1999 empirical study of the PCS auction, applying the methodology which they developed to the AWS-1 auction (auction 66), held from August to September 2006. Cramton and Schwartz describe their methodology:

> To find the retaliating bids and code bids in the DEF auction, we needed a consistent way to comb through the 23,157 bids, looking for those bids resembling those examples in Section 3. Our strategy was to loop through each bid, to tentatively assume the bid was a retaliating bid, and then to check whether the bid met criteria characteristic of retaliating bids. For each bid, we used the reported information to determine which bidder made the bid, which bidder it bumped when it placed the bid (i.e., the standing high bidder as of the prior round), the market and block, and the round the bid was placed. For a bid to be a retaliating bid, it must be clear to the bidder being bumped that the bid was not meant to win the license, but was only meant to punish. Therefore, we first eliminated all bids made by a bidder that had shown interest by bidding on any block of the same market in the prior 10 rounds. Of course, if a retaliating bid was made in the previous 10 rounds, and then a follow-up retaliating bid was made, our algorithm did not catch the second retaliating bid—the program was designed to catch only the first retaliating bid.
>
> To be a retaliating bid, we required a clear motive: the bumped bidder must have recently been bidding for a market the retaliating bidder wanted. To ensure this, we required that the bumped bidder bumped the retaliating bidder from some license in the prior two rounds. We also required that within two rounds of placing the retaliating bid, the retaliating bidder had bid on the contested market; otherwise, it is unclear what the retaliating bid was meant to accomplish.
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> If a bid met the above criteria, then it certainly met many characteristics of a retaliating bid. Our next step was to examine all of the bids returned from the above algorithm to further check that they resemble code bidding or retaliating bidding. Sometimes by looking at the retaliating bid we learned that the bid was not intended as retaliation. For example, if the bidder had bid on this market intermittently throughout the auction, then the bid was probably not meant to punish. Looking at the bids manually, we then eliminated any results returned by our algorithm included if:
>
> > 1. The bidder did not consistently adhere to a punishment strategy. If it punished once and it was not successful in deterring its rival, and then no follow-up retaliating bids were placed, then we did not view this as a retaliating bid.
> >
> > 2. The retaliating bid worked too quickly. If only one retaliating bid was placed and on a market the retaliating bidder had shown interest on earlier in the auction, if the retaliating bid did not contain a relevant market number, and if the competitor conceded, then we view this as coincidental, and not strong enough evidence to conclude that this was a retaliating bid.
> >
> > 3. The intentions of the bidder were unclear. If the bidder and the punished bidder were competing contemporaneously on several markets, and the punishing bid did not contain a market number, then we view these bids as being ambiguous in intent.

> 4. The punished bidder did not securely hold the high bid on the license being punished. If a third bidder was bidding on this market in the three rounds prior to the punishing bid, then it is not clear that the punishment had any bite.[14]

Since changes to FCC auction rules since the PCS auction have made code bidding impossible, identification of code bidding was not necessary in this study. Furthermore, while Cramton and Schwartz excluded bids before the 40th round because few licenses were obtained that early and the exclusion made their analysis more tractable, it was not possible to do so in this case, because many important licenses were obtained before the 20th round. Bids in all rounds were, therefore, subjected to scrutiny. The AWS-1 auction involved 168 qualified bidders, who placed 16,197 bids on 1,087 licenses (the FCC held an additional 35 licenses on which no bids were placed by the end of the auction). The data used was provided by the FCC.

III. Retaliatory Bidding Occurred in the AWS-1 Auction.

The algorithms described above identified 371 candidates for retaliatory bids from among 16,197 bids in the AWS-1 auction. Examination of these candidate bids for subjective factors in 1-4 in the Cramton-Schwartz methodology identified 31 of these as retaliatory bids. These bids were then designated as successful if the signaling bidder placed the winning bid on the license it sought within five rounds of placing its retaliating bid(s); unsuccess was simply the absence of success Table 1 presents this distribution:

[14] Ibid, 8-9.

Table 1.
Retaliatory Bids in the AWS-1 Auction

	BEA[15]	CMA[16]	Total
Successful	7	6	13
Unsuccessful	5	13	18
Total	12	19	31

Retaliatory bids constituted, thus, 0.19 percent of all bids placed in the AWS-1 auction. In the PCS auction Cramton and Schwartz identified 37 instances of retaliatory bidding, or 0.16 percent of all bids placed in the PCS auction. However, 23 of these bids constituted code bidding, which was not available to bidders in the AWS-1 auction, leaving 14 cases of retaliatory of the sort identified in the AWS-1 auction, or 0.06 percent of the PCS bids. It is clear that retaliatory bidding has increased in the AWS-1 auction over the rate found by Cramton and Schwartz in the PCS auction. The rate of successful retaliation has decreased slightly in the AWS-1 auction, 41.94% versus 51.35%. Retaliatory bids in the AWS-1 auction were significantly more likely to be successful for the BEA licenses than the CMA licenses; this is almost certainly an artifact of the higher rates of competition seen for the CMA licenses. No retaliatory bids on REAG licenses were observed. It should be noted that retaliatory bidding took place in an auction in which the general rate of competition – an average of three bidders per license – was regarded by the FCC as sufficiently high to eliminate it as a serious possibility.

[15] There were 176 20 MHz licenses in the Basic Economic Area B Block (BEA) and 176 10 MHz licenses in the 10 MHz Basic Economic Area (BEA) C Block.

[16] There were 734 20 MHz licenses in the Cellular Market Area A Block.

IV. Demand Reduction Effects From Retaliatory Bidding Were Observed in the AWS-1 Auction.

The indirect demand reduction effects of signaling arise from awareness on the part of bidders – and not just the bidder retaliated against – that others bidders are willing to engage in retaliatory bidding. This awareness creates risk aversion on the part of potentially threatened bidders who respond by avoiding challenging those bidders suspected of retaliatory bidding lest they become victims of retaliation themselves. In these circumstances it becomes irrelevant whether a retaliatory bidder's retaliations are successful a majority of the time, since there is no way to predict how effective a future retaliation will be. As a result, bidders who engage in retaliatory bidding are likely to acquire spectrum at lower prices than those who do not employ retaliatory bidding.[17] Demand reduction was indirectly measured by comparison of the mean price (measured as dollars/Mhz/population) paid for spectrum by bidders which used retaliatory bidding to that paid by bidders who did not. The mean price for spectrum paid by bidders who used retaliatory $0.092 per MHz/pop. The mean price for similar spectrum paid by bidders who did not use retaliatory bidding was $0.156 per MHz/pop (approximately 70% more). A two-tailed t-test of the difference between the means was significant at $p = 0.0125$.[18] Retaliatory bidding significantly reduced prices for licenses for those bidders who engaged in it. This confirms the Cramton-Schwartz finding that indirect demand reduction effects are present when signaling occurs.

[17] This is the reason why even relatively small rates of retaliatory bidding can have considerable demand reduction effects.

[18] A two-tailed t-test assesses whether the means of two groups are statistically different from each other. A p value of 0.0125 indicates that 1.25 times out of a hundred you would find a statistically significant difference between the means by random chance even if there was none, i.e., a 98.75 percent chance that the significant difference is genuine.

V. Conclusions.

Careful examination of the evidence from the AWS-1 auction leads to a number of salient conclusions:

• Signaling remains a problem in FCC spectrum auctions; while code bidding was eliminated by a rule change, no effective measure against retaliatory bidding has been adopted.

• Signaling in the form of retaliatory bidding took place in the AWS-1 auction a slightly higher rate than in the PCS D, E, and F Block auction. This was despite the claim that a modified eligibility ratio greater than three would eliminate it.

• Retaliatory bidding in the AWS-1 auction resulted in indirect demand reduction as evidenced by the significantly lower prices paid by retaliatory bidder for spectrum than by bidders who did not engage in retaliatory bidding.

• Signaling in the form of retaliatory bidding depends on the ability of retaliating bidders to identify target bidders and the licenses on which they are bidding. Anonymous bidding in the AWS-1 auction would have prevented this phenomenon entirely. As a side note, I offer that the results of the AWS-1 auction completely confirm my contentions in opposition to relaxing of the originally proposed anonymous bidding rules for the auction.[19]

• The incumbents were wrong and their opponents were right. Retaliatory bidding continued in the AWS-1 auction.

[19] "Written Ex Parte Statement of Dr. Gregory Rose on Behalf of NHMC, *et al.* in Opposition to the Proposed 'Compromise' on Anonymous Bidding," WT Docket No. 05-211/ AU Docket No. 06-33, April 5, 2006.

VI. Recommendations.

Anonymous bidding remains the only strategy for effectively defeating retaliatory bidding and other forms of tacit collusion.[20] Peter Cramton has argued for anonymous bidding:

> Concealing bidder identities. This prevents the use of targeted punishments against rivals. Unless there are strong efficiency reasons for revealing identities, anonymous auctions may be preferable.[21]

Other economists have pointed out the anti-collusive benefits of anonymous bidding. Paul Klemperer makes some useful points in a discussion of sealed-bid auctions:

> The general conclusion is that ascending auctions are more susceptible to collusion, and this is particularly the case when, as in our example, many auctions of different car models and different consumers are taking place simultaneously. As has been observed in the US and German auctions of radio spectrum, for example, bidders may be able to tacitly coordinate on dividing up the spoils in a simultaneous ascending auction. Bidders can use the early rounds when prices are still low to signal their views about who should win which objects, and then, when consensus has been reached, tacitly agree to stop pushing prices up. The same coordination cannot readily be achieved in simultaneous sealed-bid auctions, where there is neither the opportunity to signal, nor the ability to retaliate against a bidder who fails to cooperate. The conclusion is less stark when there are many repetitions over time, but it probably remains true that coordination is easier in ascending auctions. Furthermore, as is already well understood in the industrial-organization literature, this conclusion is strengthened by the different observabilities of internet and dealer sale prices which make mutual understanding of firms' strategies, including defections from "agreements," far greater in the internet case… Furthermore, this analysis ignores the impact of auction type on new entry
> in the presence of asymmetries. Because an "ascending" auction is generally efficient, a potential competitor with even a slightly higher cost (or lower quality) than an incumbent will see no point in entering the auction. However, the same competitor might enter a sealed-bid auction which gives a weaker bidder a shot at winning. The extra competition may lower prices very substantially. Of course the entry of the weaker competitor may also slightly reduce efficiency, but if competition is desirable per se, or if competition itself improves efficiency, or if the objective is consumer welfare

[20] High reserve prices have also been suggested as a remedy on the theory because the benefit from demand reduction decreases as reserve prices increase and high reserve prices reduce the number of rounds over which bidders can negotiate a collusive allocation at relatively low prices. The principal problem is that the FCC has historically been dreadful at setting reserve prices which match market valuations: in 36.21% of auctions licenses have failed to clear at reserve price even with FCC reductions of reserve price during bidding a commonplace (cf. Gregory F. Rose and Mark Lloyd, "The Failure of FCC Spectrum Auctions," Center for American Progress, 2006). It is difficult to see how such reserve prices can be fine-tuned to eliminate demand reduction without leaving substantial numbers of licenses uncleared at an auction's conclusion. Larger license sizes have also been recommended as conducive to retarding demand reduction on the grounds that larger licenses would attract higher prices. While larger licenses might retard demand reduction generally, it does not address the necessary condition for signaling and this solution ignores the chilling effect significant license size increases across the board would have on small bidder participation.

[21] Peter Cramton, "Spectrum Auctions," in M. Cave, S. Majumdar, and I, Vogelsang, eds., *Handbook of Telecommunications Economics* (Amsterdam, 2002), 605-639). The passage is a quotation from Cramton's and Schwartz's 2002 article.

> rather than efficiency, then the case for sealed-bid auctions is very strong…[22]

Sealed bidding in standard first-price auctions performs the same functions as anonymous bidding in ascending auctions: it limits opportunities for collusion and reduces the likelihood that the presence of large bidders will deter smaller bidders from entry.

The principal arguments for retaining open bidding are (1) transparency, (2) the "Linkage Principle," and (3) a variant of the "Linkage Principle" which suggests that higher revenues can be obtained in situations where a bidder's valuation is dependent on the identity of bidders for geographically adjacent licenses. There seems little reason to be concerned with transparency prior to and during an auction: the need for transparency to verify bids and ensure rule compliance can be met by release of bidder identities at the end of the auction. The "Linkage Principle" has been savaged in the theoretical literature and substantial empirical evidence is now available to falsify it: the demand reduction effects of signaling and other collusive behaviors make it difficult to believe that revelation of bidder identities maximizes auction revenue. Even if one concedes that slightly higher revenues may result from open bidding when where a bidder's valuation is dependent on the identity of bidders for geographically adjacent licenses, there is no resason to believe that it necessarily offsets the demand reduction effects of signaling and it certainly does not address the entry deterrence effects of retaliatory bidding or bidder size. The question is: what strong efficiency reasons exist for open bidding? The answer is: none.

Strict anonymous bidding rules should be adopted for future FCC spectrum auctions, including the 700 MHz auction.

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[22] Paul Klemperer, *Auctions: Theory and Practice* (Princeton, 2004), 86-87.